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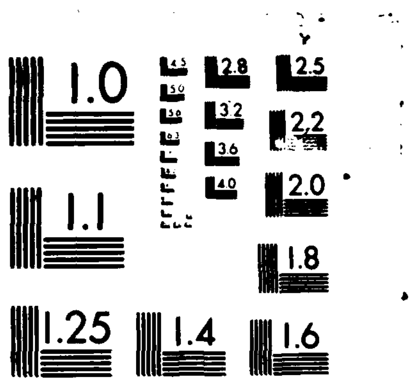

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NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 4-87

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By:

LCDR M. E. KNAFELC, MC, USN

NAVY EXPERIMENTAL DIVING UNIT

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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407-5001

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20. ABSTRACT (continue on reverse side if necessary and identify by block number)

The effectiveness of a beanie to improve communication and provide helmet noise attenuation was assessed. Eight male divers dove repeatedly on air to 6, 60, 130 and 190 FSW wearing the MK 12 SSDS helmet in the normal configuration and with a communication beanie. A Modified Rhyme Test performed at depth showed the beanie significantly improved speech intelligibility. The divers' hearing threshold levels were measured pre and immediately post dive. The temporary threshold shifts as a result of the noise exposures did not vary significantly as a function of helmet configuration or depth. However, the auditory data showed that auditory threshold shifts recovered during resting decompression. These findings indicate that present U.S. Navy diving procedures for diving the MK 12 SSDS in air do not lead to permanent hearing damage. Furthermore, the communication beanie significantly improved speech intelligibility.

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Table of Contents

		Page
Report Documentation Page		ii
Table of Contents		iv
Abstract		v
Section		
I.	INTRODUCTION	1
II.	METHOD	1
III.	RESULTS	2
IV.	DISCUSSION	3
V.	CONCLUSIONS	4
References		6
Table 1		7

ABSTRACT

The effectiveness of a beanie to improve communication and provide helmet noise attenuation was assessed. Eight male divers dove repeatedly on air to 6, 60, 130 and 190 FSW wearing the MK 12 SSDS helmet in the normal configuration and with a communication beanie. A Modified Rhyme Test performed at depth showed the beanie significantly improved speech intelligibility. The divers' hearing threshold levels were measured pre and immediately post dive. The temporary threshold shifts as a result of the noise exposures did not vary significantly as a function of helmet configuration or depth. However, the auditory data showed that auditory threshold shifts recovered during resting decompression. These findings indicate that present U.S. Navy diving procedures for diving the MK 12 SSDS in air do not lead to permanent hearing damage. Furthermore, the communication beanie significantly improved speech intelligibility.

KEY WORDS:

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NAVSEA Task No. 86-16
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Modified Rhyme Test
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Speech

I. INTRODUCTION

The MK 12 Surface-Supplied Diving System (MK 12) is used for fleet salvage and ship husbandry operations. A previous study reported high noise levels within the MK 12 helmet when the gas flow rate was 6 actual cubic feet per minute (acfm) (1). A 6 acfm flow rate is necessary to ventilate the helmet of the carbon dioxide produced during hard work and emergency situations (2). These studies also showed the noise level inside the helmet increased as the supply pressure increased with depth as necessary to maintain gas flow (1). Because the noise level can be very annoying and interfere with communications from the surface, divers may reduce their air supply when communicating with topside personnel. This can result in hypercapnia and possible unconsciousness. Also, continuous exposure to high noise levels can result in permanent hearing loss.

A communication beanie developed for saturation diving helmets was adapted for use with the MK 12. This study evaluated the beanie's effectiveness in improving communications and reducing noise exposure for the diver.

II. METHOD

Subjects

Eight U.S. Navy divers trained in the MK 12 (Air mode) participated in this study. All were audiometrically screened using a standard audiogram and did not exceed a 20 dB hearing loss at the frequencies of 3,000 and 4,000 Hz in either ear. Furthermore, each diver-subject underwent a temporary threshold shift (TTS) screening test to eliminate anyone who was unusually sensitive to loud noise. The selected divers had daily audiograms for 5 consecutive days prior to the actual study to ensure the reproducibility and reliability of the audiograms .

The dives were conducted in the Ocean Simulation Facility, located at the Navy Experimental Diving Unit. The diver-subjects dove the following profiles using the U.S. Navy Standard Air Tables:

1.8 MSW	(6 FSW)/60 minutes
18.3 MSW	(60 FSW)/60 minutes
39.6 MSW	(130 FSW)/30 minutes
57.9 MSW	(190 FSW)/20 minutes

The total dive time for all profiles was approximately 60 minutes. Each diver-subject made 2 dives on each profile. The first dive used the MK 12 in its normal configuration. The second dive had the MK 12 microphone and earphones placed in a MK 14 communication beanie (3). The communication beanie is a nylon skull cap which is adjustable to the diver's head. The earphones are placed directly over the diver's ears. The microphone with a short boom is attached to the chin strap. The communication beanie's original

circumaural ear pieces were replaced by formcut Scotfelt Afonic Foam (80 pores per inch) (Scotfoam, Eddystone, PA) which was also used on the outside of each earphone, thus attempting to provide the diver with some noise attenuation from the gas flow.

Helmet gas flow was determined by regulating helmet supply pressure and measuring differential pressure (ΔP) in a laminar flow element (LFE) (Meriam Instruments, Cleveland, Ohio: Serial Number M-5428-12) used in this study. The flow was maintained at 6.0 ± .1 acfm while the diver was at depth. Flow was reduced to 3.0 - 3.2 acfm during each decompression stop, simulating fleet procedures (2). These flows were determined by a computer generated nomogram for that particular LFE correcting for helmet temperature and depth.

The effectiveness of the beanie in attenuating the noise to the diver's ears was determined by the diver-subject TTS. An audiogram was done at the beginning of the day before the dive, and a post-dive audiogram was performed within 3 minutes after the helmet was removed.

Background noise within the audio booth was measured by frequencies in 1/3 octave band with a one-inch pressure response condensor microphone, Bruel and Kjaer (B&K), (Copenhagen, Denmark) Type 4144; pre-amplifier, B&K Type 2619; and digital frequency analyzer, B&K Type 2131 (4). The noise level was within ANSI Standards S3.1 - 1977, Table II (5). The CO_2 levels within the audio booth never exceeded 0.4%. Helmet noise levels were recorded in a similar fashion as the audio booth background noise except for using a half-inch pressure response condensor microphone, B&K, Type 4234.

The Modified Rhyme Test (MRT) was used to measure the communication intelligibility (6). By speaking directly to the diver-subjects, a surface baseline was determined for all divers prior to the dive. The same speaker conducted the test throughout this study. Approximately 10 minutes into each dive, a MRT utilizing 50 words was performed. The results were graded and the percent correct calculated using the following formula (6):

$$\% \text{ Correct} = (\text{No. Right} - \text{No. Wrong}/4) \times 2$$

III. RESULTS

On the surface, dry, in air, the mean score on the MRT was 95.9% (SD=4.0). To assess the effects of the communications beanie on speech intelligibility across the test depths, a two-way repeated measures analysis of variance technique was employed (7). The wearing of the communications beanie significantly increased the scores of divers on the MRT, when compared to scores by the divers using the normally configured MK 12 helmet [$F(1,7) = 17.91$, $p < .01$]. The average MRT score across all depths using the beanie was 75.8% (SD=11.2); without the beanie it was 66.7% (SD=11.0). There were no significant changes in speech intelligibility scores as a function of depth or depth by configuration interaction (i.e. the degree of superiority of the beanie configuration to the normal MK 12 configuration did not vary substantially across depths).

To analyze the audiogram data, the magnitude of the difference between the pre and post dive hearing threshold levels (HTLs) at each frequency for each diver was calculated. These shifts in HTL were then summed across frequencies for both ears to obtain a single value representing the shift for that dive. A two-way repeated measures analysis of variance (7) was used to determine the effects of helmet configuration and depth on HTLs. No difference in HTLs was found as a function of helmet configuration. However, there were significant differences in threshold shifts as a function of depth [$F(3,7) = 9.07$, $p < .01$]. Multiple comparisons among the depth means were then undertaken using Duncan's Multiple Range Test (8). Threshold shifts were significantly less at 1.8 MSW (6 FSW) when compared to all other depths. There were no statistically significant differences among any other depths in the magnitude of HTLs. All audiograms returned to pre-dive levels.

The helmet noise level at 1.8 MSW (6 FSW) was 90.5 dB(A).

IV. DISCUSSION

Previous NEDU studies reported the MK 12 helmet supply pressure directly affects the sound intensity level in the helmet (loudness). As supply pressure increases with depth in order to maintain the proper gas flow, helmet noise level increases.

The noise level within the helmet was recorded during the 1.8 MSW (6 FSW) dives approximated the noise levels observed on the 1986 NEDU Air Saturation Dive (1). The methods used to regulate gas flow to the helmet were the same for both studies and produced similar noise levels.

Attempts to determine the helmet noise levels at the various test depths were made with the ½-inch microphone. Unfortunately, the microphone attenuation at depth varied inconsistently when the microphones were pressurized repeatedly as per our dive schedules versus remaining at depth for a prolonged time, as in a saturation dive. Even after 30 minutes at a stable depth, the microphone sensitivity varied to such a degree as to yield unreliable data. No further attempt was made to determine the actual noise level within the helmet.

Sound measurements during the 1986 NEDU Air Saturation Dive yielded helmet noise levels of 90.5 dB(A) at 1.8 MSW (6 FSW). Helmet noise levels increased to 96.3 ± 0.6 dB(A) at 20.1 MSW (66 FSW) and 97.3 dB(A) at 30.5 MSW (100 FSW) (1). Based on the above data and experience with other diving helmets (4, 9), it is predicted that as depth increases the noise level will continue to increase. As depth increases the supply pressure must also increase to maintain the same gas flow rate. Thus, the increased noise levels may be a function of the mass flow through the supply and/or exhaust orifices. Since we had no accurate measure of helmet noise in this study, we ensured similar supply pressure and helmet flow appropriate for each depth and condition.

It is believed that the diver-subjects were exposed to higher helmet noise levels at deeper depths. However, the largest TTS was seen at 18.1 MSW

(60 FSW). This pattern of TTS can be explained by examining the noise dose received by the diver. The diver-subject at 18.1 MSW was exposed to a constant 96 dB(A) for 60 minutes. On the deeper dives, the noise exposure associated with gas flow of 6.0 acfm was 30 min at 39.6 MSW (130 FSW) and 15 or 20 min at 57.9 MSW (190 FSW). Though the maximum sound intensity level in the helmet was louder during the deeper dives, the gas flow reduction to 3.0 acfm during decompression sufficiently lowered the noise level to allow the ear to recover. This recovery pattern was observed in both MK 12 configurations. Furthermore, due to concerns unrelated to this study, the bottom time for the 57.9 MSW (190 FSW) beanie dive was limited to 15 min. There was no significant difference in the median TTS in the beanie configuration from the median TTS with a 20 min exposure in the standard MK 12.

Applying the Navy's hearing conservation standards, OPNAVINST 6260.2, the data from the 1986 NEDU Air Saturation Dive indicated that the MK 12 (air mode) using 6.0 acfm gas flow should be restricted to a 120 min exposure at 9.1 MSW (30 FSW), a 60 min exposure at 20.1 MSW (66 FSW), and a 50 min exposure at 30.5 MSW (100 FSW) (1). Though actual helmet noise levels were not recorded during these bounce dives, it is believed the sound levels in the helmet would be louder at 39.6 MSW (130 FSW) and at 57.9 MSW (190 FSW) and therefore would decrease the allowable exposure time . The evidence that recovery of hearing was underway by the time the diver-subject reached the surface on the deeper dive profiles suggests that the noise exposure of 6.0 acfm at the deeper depths does not exceed current Navy hearing conservation standards. Furthermore, the 6.0 acfm gas flow is used only during periods of heavy work and emergency situations, and the U.S. Navy Diving Manual restricts this flow duration to 10 min.

Communication intelligibility was diminished for the diver-subjects when using the standard MK 12. The communication beanie significantly improved the diver-subject's ability to understand speech from personnel on the surface. However, improvement did not match the surface baselines obtained without using the communication system. This may be due to either the helmet noise which cannot be filtered out or the intrinsic limitations of the communication system [the Tethered Diver Communication System (TDCS)], or their combination. A study evaluating the degradation in speech intelligibility attributed to the TDCS alone would be informative. Possibly of greater significance is the current MK 12 microphone. It is responsive to sounds at 300-12,000 hertz but it is particularly sensitive to high frequencies. Such sensitivity is inappropriate since human speech is in the frequency range of 500-4000 Hertz. When placed in the communication beanie it lies in the gas flow. This noise is picked up by the TDCS and relayed to the diver's ears. This noise may mask the high frequency sounds of speech and thus affect intelligibility.

V. CONCLUSIONS

The beanie appears to improve communications within the MK 12. Replacing the current helmet microphone with one that has a sensitivity between 500-4000 hertz may further increase speech intelligibility.

The current MK 12 noise study tested the worst case scenario. An exposure to the noise generated by 6.0 acfm gas flow is currently limited to 10 min which appears safe for the diver, regardless of depth.

The actual noise level produced by a 4.5 acfm flow within the MK 12 helmet has not been determined. A. 4.5 acfm is the maximum flow allowed for an unlimited duration in the U.S. Navy (2). It may be inferred from the worst case testing that this flow would not generate noise inside the helmet which would lead to a reduction in the allowable diving time. Therefore, no restrictions need be placed on the MK 12 SSDS, air mode, when dove according to standard Navy procedures.

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TABLE 1. The mean percent correct on the Modified Rhyme Test as a function of MK 12 helmet configuration and depth. N=8 dives for each mean; standard deviations are in parentheses.

Table of Means (% correct)

	Normal Configuration		Beanie	
Depth	$\bar{X}$	(SD)	$\bar{X}$	(SD)
6 FSW	69	(9)	85	(11)
60 FSW	67	(12)	75	(12)
130 FSW	70	(10)	75	(8)
190 FSW	61	(12)	72	(11)

TABLE 2. The mean hearing threshold level shifts across frequencies for dives in both MK 12 helmet configurations. N=8 dives for each mean; standard deviations are in parentheses.

Table of Means (dB)

	Normal Configuration		Beanie	
Depth	$\bar{X}$	(SD)	$\bar{X}$	(SD)
6 FSW	39	(48)	30	(33)
60 FSW	97	(47)	76	(70)
130 FSW	64	(58)	76	(47)
190 FSW	71	(60)	66	(51)

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